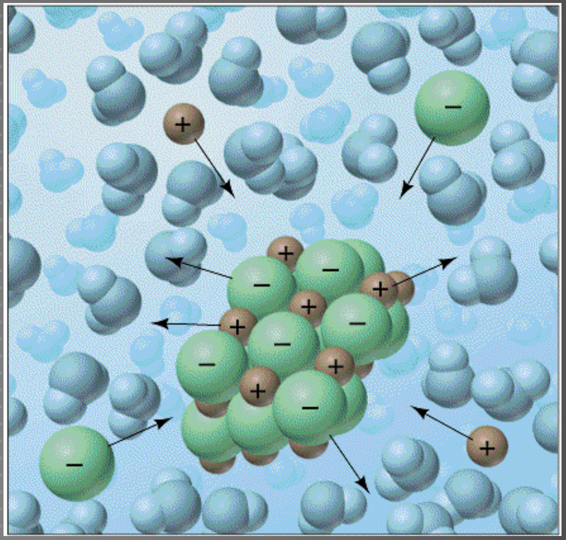
SOLUBILITY PRODUCT & COMMON ION EFFECT

SOLUBILITY

- Describes the chance of a substance dissolving in water using the following rules:
  - Most nitrate (NO_3^-) and acetate ($C_2H_3O_2^-$) salts are soluble.
  - Most salts containing the alkali metal ions (Li^+, Na^+, K^+, Cs^+, Rb^+) and the ammonium ion (NH_4^+) are soluble.
  - Most chloride, bromide, and iodide salts are soluble. Notable exceptions are salts containing the ions Ag^+, Pb^{2+}, and Hg_2^{2+}.
  - Most sulfate salts are soluble. Notable exceptions are $BaSO_4$, $PbSO_4$, Hg_2SO_4, and $CaSO_4$.
  - Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH and KOH. The compounds $Ba(OH)_2$, $Sr(OH)_2$, and $Ca(OH)_2$ are only slightly soluble.
  - Most sulfide (S^{2-}), carbonates (CO_3^{2-}), chromate (CrO_4^{2-}), and phosphate (PO_4^{3-}) salts are only slightly soluble.

SOLUBILITY PRODUCT

- Equilibrium established between salt and ions
- Constant for this equilibrium is known solubility product (K_{sp})
  - Salts producing same number of ions, K_{sp} can be used to measure the extent to which the solid dissolves
  - Larger K_{sp} = more soluble the salt



EXAMPLE #1

- Given the following salts and their K_{sp} values, which salt is the most soluble? Which salt is the least soluble?

Formula	K_{sp}
$NiCO_3$	1.4×10^{-7}
MnS	2.3×10^{-13}
$CaSO_4$	6.1×10^{-5}

Most soluble = largest value for K_{sp} ($CaSO_4$)

Least soluble = lowest value for K_{sp} (MnS)

SOLUBILITY CALCULATIONS

- Solubility—amount of salt that will dissolve in 1 L of water
  - Can be given in units of mol/L or g/L
- Two types of calculations:
  - Calculating K_{sp} from Solubility
  - Calculating Solubility from K_{sp}

EXAMPLE #2

- The solubility of $Pb_3(PO_4)_2$ is 6.2 x 10^{-12} M. Calculate the K_{sp} value for the solid.

$$Pb_3(PO_4)_2\ (s) \leftrightarrow 3\ Pb^{2+}\ (aq) + 2\ PO_4^{3-}\ (aq)$$

I	---------	0	0
C	---------	+3x	+2x
E	---------	3x	2x

$$K_{sp} = [Pb^{2+}]^3[PO_4{}^{3-}]^2 = (3x)^3(2x)^2 = 108x^5$$
$$x = 6.2\ x\ 10^{-12}\ M$$
$$K_{sp} = 108\ (6.2\ x\ 10^{-12})^5 = 9.9\ x\ 10^{-55}$$

EXAMPLE #3

- Given the two salts in the table below, which is more soluble?

Formula	K_{sp}
FeC_2O_4	2.1×10^{-7}
$Cu(IO_4)_2$	1.4×10^{-7}

Cannot compare K_{sp} because they produce different number of ions so must calculate solubility

$$FeC_2O_4\ (s) \leftrightarrow Fe^{2+}\ (aq) + C_2O_4^{2-}\ (aq)$$

$$K_{sp} = [Fe^{2+}][C_2O_4^{2-}] \rightarrow 2.1\ x\ 10^{-7} = x^2$$

$$x = 4.6\ x\ 10^{-4}\ M\ Fe^{2+}$$

$$4.6\ x\ 10^{-4}\ M\ Fe^{2+} = 4.6\ x\ 10^{-4}\ M\ FeC_2O_4$$

EXAMPLE #3

$Cu(IO_4)_2$ (s) ↔ Cu^{2+} (aq) + 2 IO_4^{2-} (aq)

$$K_{sp} = [Cu^{2+}][IO_4^-]^2 \rightarrow 1.4\ x\ 10^{-7} = 4x^3$$

$$x = 3.3\ x\ 10^{-3}\ M\ Cu^{2+}$$

$$3.3\ x\ 10^{-3}\ M\ Cu^{2+} = 3.3\ x\ 10^{-3}\ M\ Cu(IO_4)_2$$

Solubility of $Cu(IO_4)_2$ > Solubility of FeC_2O_4

COMMON ION EFFECT

- Salt added to water with a common ion will reduce the solubility of salt
- Example #4: Calculate the molar solubility of Ag_2SO_4 in 0.10 M $AgNO_3$ (K_{sp} = 1.2 x 10^{-5}).

$$Ag_2SO_4\ (s) \leftrightarrow 2\ Ag^+\ (aq) + SO_4^{2-}\ (aq)$$

I	---------	0.10	0
C	---------	+2x	x
E	---------	0.10 + 2x	x

$$K_{sp} = [Ag^+]^2[SO_4^{2-}] = (0.10 + 2\text{x})^2(x) \approx (0.10)^2(x)$$
$$x = 1.2\ x\ 10^{-3}\ M\ SO_4^{2-} = 1.2\ x\ 10^{-3}\ M\ Ag_2SO_4$$

PRECIPITATE FORMATION

- Concentrations of ions involved into the formation of a solid determines if a precipitate will form
- Ion product (Q_{sp}) used to predict if a precipitate is formed
  - Calculated the same way as K_{sp}
  - Involves the initial concentrations instead of the equilibrium concentrations
- Comparison of Q to K_{sp}
  - $Q_{sp} > K_{sp}$: precipitation occurs
  - $Q_{sp} < K_{sp}$: no precipitation occurs
  - $Q_{sp} = K_{sp}$: solution is saturated